ART 34 AMDT

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CLAIMS

What is claimed is:

1. An apparatus comprising an oxygen sensor including a ferroelectric metal oxide sensing member having an effective operating temperature below about 400K.

2. An apparatus comprising an oxygen sensor including a non-stoichiometric metal oxide sensing member having at least two compositional constituents in a ratio that increases along a predetermined direction through said sensing member to provide a corresponding compositional gradient, said non-stoichiometric metal oxide having an effective operating temperature below about 400K.

3. The apparatus of claim 1 or 2 having an effective operating temperature below about 375K.

SUB A1

4. The apparatus of claim 1 or 2 having an effective operating temperature below about 300K.

5. The apparatus of claim 1 or 2, wherein said sensor includes at least two metallic electrodes.

6. The apparatus of claim 5, wherein said electrodes are formed from a material selected from platinum, silver, gold, metal phthalocyanine, and conductive metal oxide.

SUB A2

7. The apparatus of claim 1 or 2 and further comprising a circuit electrically coupled to said sensing member operable to apply a time varying electric field to said sensing member.

8. The apparatus of claim 2, wherein said at least two compositional constituents are zirconia and titania.

9. The apparatus of claim 2 or 8, wherein said gradient is established by a number of differently composed layers.

10. The apparatus of any of claims 1 or 2, wherein said sensing member is formed of $PbZr_xTi_yO_3$; where x is in a range of about 0.5 to about 0.8 and y is in a range of about 0.2 to about 0.5.

11. The apparatus of claim 10, wherein x increases along a direction through said sensing member and y decreases along said direction.

12. The apparatus of claim 11, wherein x is in a range of about 0.55 to about 0.75 and y is in a range of about 0.25 to about 0.45.

13. The apparatus of claim 10, wherein said sensing member includes a number of layers each having a different ratio of x to y.

14. The apparatus of claim 10, wherein x is about 0.55 and y is about 0.45 along a first surface of said sensing member and x is about 0.75 and y is about 0.25 along a second surface of said sensing member opposite said first surface.

SUB A1

15. The apparatus of claim 1 or 2, wherein said sensing member is comprised of an oxygen deficient ionic oxide material.

16. The apparatus of claim 15 wherein the said sensing member is comprised of a YSZ material.

SUB A2

17. A method of use, comprising detecting oxygen in an intake or exhaust stream of a vehicle with the apparatus of claim 1 or 2.

Sub A6

18. A method of manufacture, comprising:

providing a source of ferroelectric material having a first region with a first composition and a second region with a second composition different from the first composition;

irradiating a portion of the first region and a portion of the second region with a laser to release a mixture from the source with a predetermined ratio of the first composition to the second composition; and

forming a layer of a sensing matrix from the mixture, the mixture corresponding to the ratio.

19. The method of claim 18, wherein said source is a solid composed of $PbZr_xTi_yO_3$; where x and y have a first predetermined ratio in the first region and a second predetermined ratio in the second region, the first predetermined ratio being different from the second predetermined ratio.

20. The method of claim 19, wherein x is about 0.75 in the first region and about 0.55 in the second region and y is about 0.25 in the first region and about 0.45 in the second region.

21. The method of claim 18, wherein the first region is adjacent the second region with an interface oriented at a predetermined position relative to the laser.

22. The method of any of claims 18-21 further comprising performing said irradiating of a number of different portions of the first and second regions to form a graded ferroelectric sensing member.

SUB A7

23. The method of any of claims 18-21, wherein said irradiating includes scanning a predetermined path along the source with the laser.

24. The method of claim 23, wherein said path includes a number of different segments each corresponding to a different ratio of the first composition to the second composition.

Cont A7

25. The method of any of claims 18-21, wherein said forming includes depositing the mixture on a substrate.

26. An oxygen sensor formed by the method of any of claims 18-21.

27. A method of manufacture, comprising:

providing a source of ferroelectric material having a first region with a first composition and a second region with a second composition different from the first composition;

generating a number of plumes each having a different ratio of the first composition to the second composition, each of the plumes being formed from different areas of the first and second regions; and

forming a number of layers each corresponding to a different one of the plumes, the layers each having the different ratio of the first composition to the second composition to provide a ferroelectric device with a predetermined compositional gradient.

28. The method of claim 27, wherein the source is a solid composed of $PbZr_xTi_yO_3$; where x and y have a first predetermined ratio in the first region and a second predetermined ratio in the second region, the first predetermined ratio being different from the second predetermined ratio.

29. The method of claim 28, wherein x is about 0.75 in the first region and about 0.55 in the second region and y is about 0.25 in the first region and about 0.45 in the second region.

30. The method of claim 27, wherein the first region is adjacent the second region with an interface oriented at a predetermined position relative to a device for performing said generating.

SUB A8

31. The method of any of claims 27-30, wherein said generating the plumes includes irradiating a corresponding number of different portions of the first and second regions.

32. The method of any of claims 27-30, wherein said irradiating includes scanning across a predetermined path along the source with a laser.

33. The method of claim 32, wherein said path includes a number of segments each corresponding to a different one of the plumes.

SUB A9

34. The method of any of claims 27-30, wherein said forming includes depositing material from a first one of the plumes on a substrate.

35. An oxygen sensor formed by the method of any of claims 27-30.

36. An apparatus comprising an oxygen sensor including a PZT ferroelectric sensing member.

37. The apparatus of claim 36 wherein said sensing member is comprised of a graded ferroelectric material.

38. The apparatus of claim 36 wherein the said sensor includes at least two metallic electrodes.

39. The apparatus of claim 38 wherein said electrodes are formed from a material selected from platinum, silver, gold, metal phthalocyanine, and conductive metal oxide.

40. The apparatus of claim 36 and further comprising a circuit electrically coupled to said sensing member operable to apply a time varying electric field to said sensing member.

SUB A10

41. The apparatus of any of claims 36-40, wherein a ratio between two compositional constituents increases along a predetermined direction through said sensing member to provide a corresponding compositional gradient.

42. The apparatus of claim 41, wherein said gradient is established by a number of differently composed layers.

43. The apparatus of claim 41 or 42, wherein said two compositional constituents are zirconia and titania.

SUB A11

44. The apparatus of any of claims 36-40 wherein said sensing member is formed of $PbZr_xTi_yO_3$; wherein x is in a range of about 0.5 to about 0.8 and y is in a range of about 0.2 to about 0.5.

45. The apparatus of claim 44 wherein x is in a range of about 0.55 to about 0.75 and y is in a range of about 0.25 to about 0.45.

SUB A12

46. A method of use, comprising detecting oxygen in an intake or exhaust stream of a vehicle with the apparatus of any of claims 36-40.

47. A combination, comprising:

a nonstoichiometric metal oxide sensing member to detect oxygen; and

a circuit electrically coupled to said sensing member operable to apply a time varying electric field to said sensing member having a peak magnitude of at least about 1 volt per μm.

48. A combination, comprising:

providing a nonstoichiometric metal oxide sensing member;

applying a time varying electric field to said sensing member having a peak magnitude of at least about 1 volt per μm; and

sensing oxygen with said sensing member during said applying.

SUB A12

49. The combination of claim 47 or 48, wherein said peak magnitude is in a range of about 1 volt per µm to about 1000 volts per µm.

50. The combination of claim 49, wherein said peak magnitude is in a range of about 10 volts per µm to about 100 volts per µm.

51. The combination of claim 47 or 48 wherein said sensing member is comprised of a ferroelectric material.

SUB 13

52. The combination of claim 47 or 48, wherein said sensing member is comprised of a PZT material.

53. The combination of claim 47 or 48, wherein the system is operable to detect oxygen concentration at a temperature below about 400K.

Add A14